REVIEW ARTICLE

# EFFECT OF EXTREMELY LOW FREQUENCY ELECTROMAGNETIC FIELDS ON BRAIN ACTIVITY

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**ABSTRACT**
Both natural and artificial extremely low frequency (ELF) electromagnetic fields (EMF) are reportedly found to be biologically active. Exposure effects of high frequency and high intensity EMFs especially from microwave devices and mobile phones are popularly discussed and researched as compared to exposure effects of ELF EMFs. Increased use of electricity during previous decades is causing greater or forced exposure to ELF EMFs. Exposure assessment of ELF EMFs in terms of health effects has proved to be a new area of research. The present study deals with effects of ELF EMFs on brain activity, electrophysiological signals and anxiety related issues. Previous efforts in this regards are identified and explored to illustrate the effects. The new areas of research are identified which can be extremely interesting for medical, bioelectromanetics and electrical engineering streams.
**Key Words:** Extremely Low Frequency (ELF); Health Effects; Electromagnetic Fields (EMF); Brain; Electrophysiological Signals

## Introduction

Peoples are exposed to ELF EMF at their workplace as well as at the place of residence. Identifying biological effects on living bodies, due to exposure to ELF EMF have gained much attention of scientists during previous years. Exposure assessment studies were carried out by considering exposure due to natural sources as well as manmade sources. There have been certain evidences which show that ELFs from manmade[1] as well as natural[2] sources are absorbed in body and hazardous to health. There are sensible scientific evidences also to establish link between Schumann resonance and sunspot relations to human health effects.[3] Various international organizations have initiated the research to determine the exact link between ELF exposure and human health.[4] Exposure guidelines have been also set internationally.[5] Growing concern about possible health effects, have caused extensive organizational and individual efforts to be carried out in this regards. Detailed review of these efforts can be found out elsewhere.[6-8]

However an effort to determine possible effects of ELF EMF on brain activity, sleep disorders[9], different electrophysiological signals and creating state of anxiety is still in its infancy. Wide research scope always exists to study effect of ELF EMFs on the modulation of brain tissue functions[10], considering the set medical hypothesis of absorption of ELF EMF by human brain[2]. Few attempts have been made by researches to study the possible exposure associated effects on behaviour, anxiety and EEG. Present study was undertaken to generate detail information about efforts carried to determine proximity effects of ELF EMF on brain activity. Exposure to ELF EMF results in inducing internal fields in body. The particular threshold value of this internal field can be the triggering element which initiates biological changes. The Results of previous studies are inconsistent due to differences in exposure levels, durations and other experimental conditions. Apart from exploring the studies related to effect of ELF EMF on brain activity, this paper also suggests new areas of research in Bio-electromagnetism, Medical and public health studies.

## General Physiology

The centre of brain consists of a pinecone shaped structure called pineal body or pineal gland. It is a sensitive biological watchdog in brain. The pineal gland secretes a hormonal signal called melatonin during the night in all species. Investigations[11] in both animals and humans have provided evidence that pineal gland plays important role in regulation of both the circadian and seasonal rhythms in variety of species. The hormonal activity associated with this gland plays role in body temperature, weight, tumoral growth and even life span too. Various in vivo, in vitro, human experimental and epidemiological studies carried out to identify effects of electromagnetic fields on melatonin are reviewed in as shown in table 1 and 2.[12]

**Table-1: Studies of the effects of magnetic fields on melatonin production**

| Exposure | Effect |
|---|---|
| 'Ion-cyclotron resonance' for calcium[13] | NA stimulation of melatonin production and release reduced |
| 50 μT, 60Hz for 12 h[14] | NA stimulation of melatonin release reduced |
| 1 mT, 50Hz for 1 h[15] | NAT activity decreased |
| 86 μT, 50Hz or 16.67 Hz for 8 h[16] | Isoproterenol stimulation of melatonin production reduced |
| 1 mT, 50Hz for 4h[17] | NA stimulation of melatonin release increased |
| 0.5 mT, 50 Hz for 4h[18] | No effect on melatonin release |

**Table-2: Studies of the effects of magnetic fields on responses of cells to melatonin or tamoxifen**

| Exposure | Effect |
|---|---|
| 1.2 μT, 60 Hz, for 7 days[19,20] | EMF exposure partially blocked melatonin ($10^{-9}$ M) inhibition in MCF-7 cells, Similar result with tamoxifen ($10^{-7}$ M) |
| 1.2 μT, 60Hz for 7 days[21] | EMF exposure partially blocked temoxifen ($2.5\ 10^{-8}$ M) inhibition of MCF-7 cells |
| 1.2 or 100 μT, 50Hz for 7 days[22] | Inhibition of DNA synthesis by melatonin ($10^{-11}$ M) partially blocked by 1.2 μT EMF exposure. 100 μT blocked cAMP inhibition by melatonin ($10^{-9}$ M) in MCF-7 celss |
| 0.3 mT pulsed for 20ms at 2 Hz for 1 h repeated over 3 days[23] | Growth of MCF-7 cells unaffected |

## Natural ELF EMF and EEG/Brain Activity

Dr. Neil Cherry has investigated that resonant absorption of the SR signal in human brains is classically sensible because of the matching of oscillating frequency ranges of the SR spectrum and EEG rhythms.[3] The Schumann Resonance signal is generated by tropical thunderstorms and is a set of resonant modes within the resonant cavity formed between the earth's surface and the D-region of the ionosphere. It consists of a spectrum of ULF/ELF resonant peaks with a fundamental frequency of about 7.8 Hz and broad resonant peaks typically at 14, 20, 26, 33, 39, 45 and 51 Hz.[2]

The first five SR modes (0-35 Hz) coincide with the frequency range of the first four EEG bands. The primary EEG frequency bands are: Delta, 0.5 to 4 Hz, Theta, 4-8 Hz, Alpha, 8-13 Hz and 13 to 30 Hz.[24] Hence resonant absorption and reaction is biophysically plausible. Dr. Cherry also showed that there is evidence of a homeostatic relation to neurological effects from altered S/GMA indices that are highly correlated with the SR signal intensity. Irena Cosic[25] investigated human electrophysiological signal responses to ELF Schumann Resonance signals. The results from this study have shown that frequencies between 8.8 and 13.2 Hz, which fall between peaks of the Schumann resonance, mainly correlate with analysed human electrophysiological signals. This study also confirms that the human body absorbs, detects and responds to ELF environmental EMF signals.

## Artificial ELF EMF and EEG/Brain Activity

ELF EMFs are also produced by different manmade sources like power generating stations and equipments operating on electrical power. With increased speed of economy, power utilization has also increased many fold. Life on earth is extensively exposed to ELF EMF produced by these artificial sources. Set hypothesis of absorption of ELF EMF by human brain or body have attracted many researchers to identify the effects on these manmade ELF ELFs on electrophysiological signals like EEG.

Study by D. Cvetkovic[26] has investigated whether extremely low frequency (ELF) electromagnetic fields (EMFs) can alter human brain activity. In this study linearly polarized magnetic flux density of 20μT (rms) was generated using a standard double Helmholtz coils and applied to the human head over a sequence of 1 minute stimulations followed by one minute without stimulation in the following order of frequencies 50, 16.66, 13,10, 8.33 and 4Hz. The results indicated that there was a significant increase in Alpha1, Alpha2, and Beta1 at the frontal brain region, and a significant decrease in Alpha2 band in parietal and occipital region due to EMF exposure.

Elif Derya Übeyli, et al presented eigenvector methods for analysis of the photoplethysmogram (PPG), electrocardiogram (ECG), electroencephalogram (EEG) signals recorded in order to examine the effects of pulsed electromagnetic field (PEMF) at extremely low frequency (ELF) upon the human electrophysiological signal behaviour.[27] The features representing the PPG, ECG, EEG signals were obtained by using the eigenvector methods.

Nicholas Perentos, et al in their study on effect of ELF radiation on the alpha band of the human resting EEG have considered the case of mobile phone emitted ELF fields.[28] Mobile phone handsets such as those operating in the GSM network emit extremely low frequency electromagnetic fields ranging from DC to at least 40 kHz. The influence of these fields on the human resting EEG has been investigated in a fully counter balanced, double blind, cross-over design study that recruited 72 healthy volunteers. A decrease in the alpha frequency band was observed during the 20 minutes of ELF exposure in the exposed hemisphere only. This result suggests that ELF fields as emitted from GSM handsets during the DTX mode may have an effect on the resting alpha band of the human EEG.

## Conclusion

- The review covered different sources of extremely low frequency electromagnetic fields and different hypothesis in relation to their effects on human health.
- Literature review indicated that the strength and exposure duration of ELF EMF has been found to be playing key role in initiating effects related to brain, anxiety, sleep disorder, behavioural studies and electrophysiological signals.
- Very Less researchers have identified the effect due to Electric field.
- Wider scope of research is identified to establish exact link between ELF and EMF (especially electric field) and electrophysiological signal behaviour. Refined research can be still carried out in determining exact threshold value, different range of frequencies and exposure scenarios too.

## References


1. Cherry N. Evidence that Electromagnetic fields from high voltage powerlines and in buildings, are hazardous to human health, especially to young children. Environmental Management and Design Division, Lincoln University. New Zealand. 2001. p. 1-60.
2. Cherry N. Schumann resonances, a plausible biophysical mechanism for the human health effects of solar/geomagnetic activity. Nat Hazards 2002;26:279–331.
3. Cherry N. Schumann Resonance and sunspot relations to human health effects in Thailand. Environmental Sciences Department, Lincoln University, Canterbury. New Zealand. 2002. p. 1-12.
4. Repacholi MH. An Overview of WHO's EMF project and the Health Effects of EMF exposure. Proceedings of the International Conference on Non-Ionizing Radiation at UNITEN (ICNIR 2003). Electromagnetic Fields and Our Health. World Health Organization, Geneva. 2003. p. 1-21.
5. The ELF Working Group. Health Effects and Exposure Guidelines Related to Extremely Low Frequency Electric and Magnetic Fields -An Overview. The Federal-Provincial-Territorial Radiation Protection Committee, Canada. 2005. 1-271.
6. California Department of Health Services and Public Health Institute. Electric and Magnetic Fields-Measurements and Possible Effects on Human Health. California Electric and Magnetic Fields Program. Canada. 2000. p. 1-8.
7. Marino AA, Becker RO. Biological Effects of Extremely Low Frequency Electric and Magnetic Fields: A Review. Physiol Chem & Physics 1977;9:131-47.
8. Maryland Power Plant Research Program. Status Report on Potential Human Health Effects Associated With Power Frequency Electric and Magnetic Fields. IVI, Maryland Department of Natural Resources and Public Service Commission of Maryland. 1994. p. 1-242.
9. Schmid MR, Loughran SP, Regel SJ, Murbach M, Bratic Grunauer A, Rusterholz T, et al. Sleep EEG alterations: Effects of Different Pulse Modulated Radio Frequency Electromagnetic Fields. J Sleep Res 2012;21:50-8.
10. Adey WR, Smith B, Adelman G. International Encyclopaedia of Neuroscience, 3rd Edi. New York: Elsevier; 1992. p. 1-21.
11. Aleandri V, Spina V, Morini A. The Pineal Gland and Reproduction", Human Reproduction Update, European Society for Human Reproduction and Embryology. 1996;2:225-35.
12. Report of an Independent Advisory Group on Non-ionising Radiation. Power Frequency Electromagnetic Fields, Melatonin and Risk of Breast Cancer. Documents of the Health Protection Agency, Series B. 2006. p. 1-180.
13. Lerchl A, Reiter RJ, Howes KA, Nonaka KO, Stokkan KA. Evidence that Extremely Low Frequency Ca(2+) Cyclotron resonance depresses Pineal Melatonin Synthesis In Vitro. NeuroSci Lett 1991;124:213-5.
14. Rosen LA, Barber I, Lyle DB. A 0.5 G, 60 Hz magnetic field suppresses melatonin production in pinealocytes. Bioelectromagnetics 1998;19:123–7.
15. Chacon L. 50 Hz Sinusoidal Magnetic Field Effect on In Vitro Pineal N-acetyltransferase activity. Electromagnetobiol 2000;19:339-43.
16. Brendel H, Niehaus M, Lerchl A. Direct Supresssive Effects of Weak Magnetic Fields (50 Hz and 16 2/3 Hz) on Melatonin Synthesis in the pineal Gland of Djungarian Hamsters(Phodopus Sungorus). J of Pineal Res 2000;29:228-33.
17. Lewy H, Massot O, Touitou Y. Magnetic Field(50Hz) Increases N-acetyltransferase, hydroxi-indole-O-Methyltransferase activity and Melatonin release through an Indirect Pathway. Int J Radiat Biol 2003;79:431-5.
18. Tripp HM, Warman GR. Circularly Polarized MF(500μT 50 Hz) does not acutely suppress melatonin secretion from Cultured Wistar Rats Pineal Glands. Bioelectromagnetics 2003;24:118-24.
19. Liburdy RP, Sloma TR, Sokolic R, Yaswen P. ELF magnetic fields, breast cancer, and melatonin: 60 Hz fields block melatonin's oncostatic action on ER+ breast cancer cell proliferation. J Pineal Res 1993;14:89-97.
20. Harland JD, Liburdy RP. Environmental Magnetic Fields inhibit the Antiproliferative action of Tamoxifen and Melatonin in a Human Breast Cancer Cell Line. Bioelectromagnetics 1997;18:555-62.
21. Blackman CF, Andrews PW, Ubeda A, Wang X, House DE, Trillo MA, et al, Physiological Levels of Melatonin Enhance Gap Junction Communication in Primary Cultures of Mouse Hepatocytes. Cell Biol Toxicol 2001;17:1-9.
22. Ishido M, Nitta H, Kabuto M. Magnetic Fields(MF) of 50 Hz at 1.2 μT as well as 100μT Cause Uncoupling of Inhibitory Pathways of Adenylyl Cyclase Mediated by Melatonin 1a Receptor in MF-Sensitive MCF-7 Cells. Carcinogenesis 2001;22:1043-48.
23. Leman ES, Sisken BF, Zimmer S, Anderson KW. Studies of the Interaction Between Melatonin and 2Hz, 0.3 mT PEMF on the proliferation and invasion of Human Breast Cancer Cell. Bioelectromagnetics 2001;22:178-84.
24. Malmivuo J, Plonsey R. Bioelectromagnetism: Principles and applications of bioelectric and biomagnetic fields. Publ Oxford Univ Press, Oxford, England. 1995.
25. Cosic I, Cvetkovic D, Fang Q, Jovanov E, Lazoura H. Human electrophysiological signal responses to ELF schumann resonance and artificial electromagnetic fields. FME Transactions 2006;34:93-103.
26. Cvetkovic D, Jovanov E, Cosic I. Alterations in Human EEG Activity Caused by Extremely Low Frequency Electromagnetic Fields. Proceedings of the 28th IEEE EMBS Annual International Conference New York City, USA. 2006. p. 3206-9.
27. Übeyli ED, Cvetkovic D, Cosic I. Eigenvector Methods for Analysis of Human PPG, ECG and EEG Signals. Proceedings of the 29th Annual International Conference of the IEEE EMBS, Cité Internationale, Lyon, France. 2007. p. 3304-7.
28. Perentos N, Croft RJ, McKenzie RJ, Cvetkovic D, Cosic I. The effect of GSM-like ELF radiation on the alpha band of the human resting EEG. 30th Annual International IEEE EMBS Conference Vancouver, British Columbia, Canada. 2008. p. 6680-3.


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